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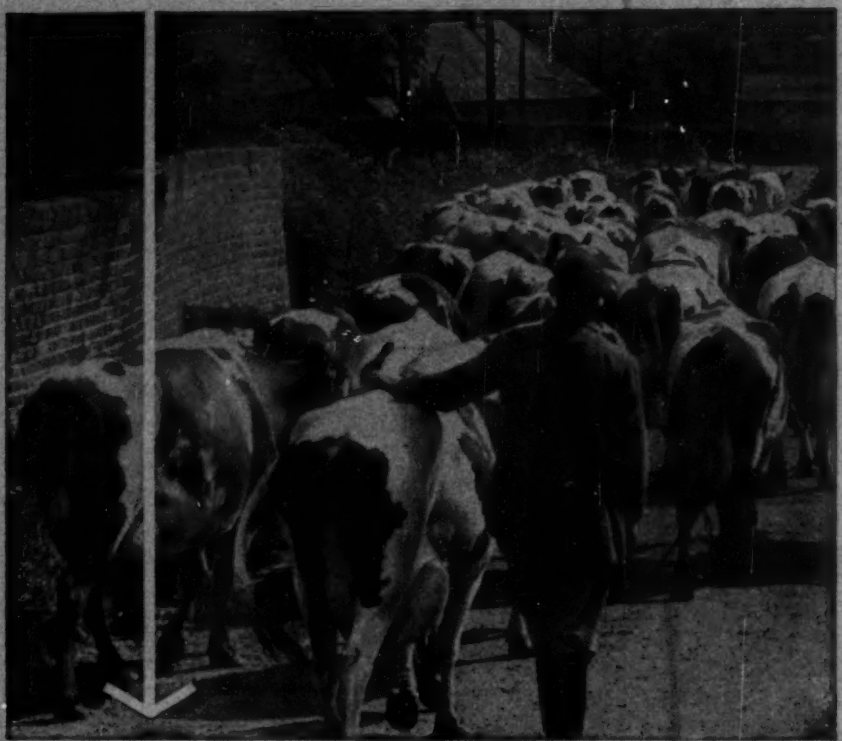

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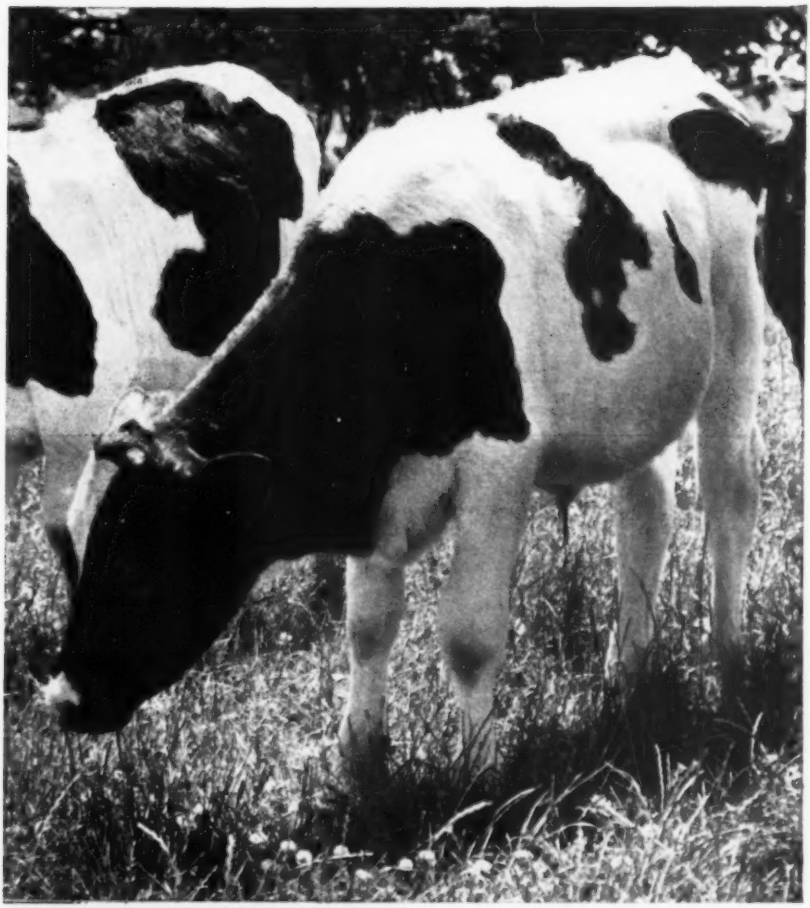

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The British Veterinary Journal

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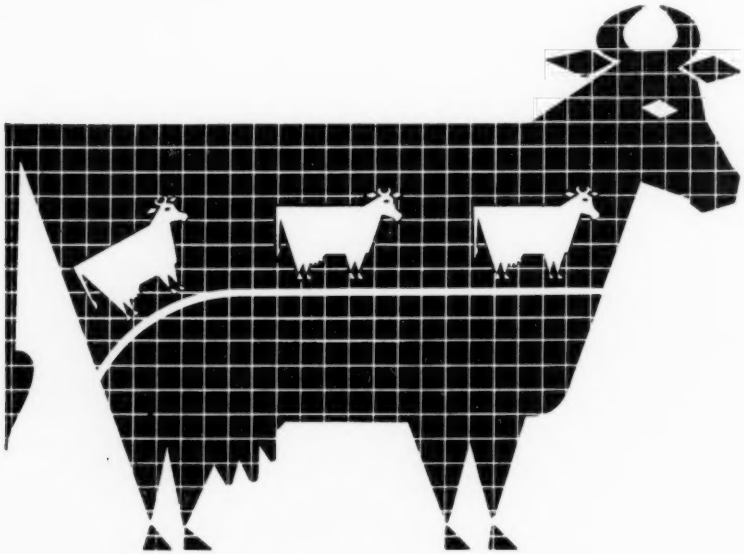

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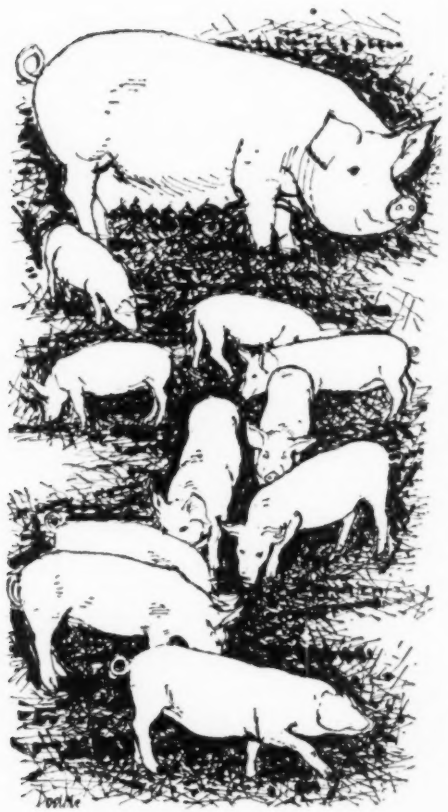

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RABIES OF FARM LIVESTOCK IN AFRICA

By J. LIBEAU

Inter-African Bureau for Animal Health, Muguga, Kenya

Rabies of farm livestock does not constitute a public health problem of first importance in Africa south of the Sahara, but it may present an economic problem of some consideration to owners whose stock are in fairly close contact with such wild carnivores as are regarded as the principal reservoirs of the disease.

In the course of a statistical survey on rabies in Africa recommended by the Inter-African Advisory Committee for Animal Health and conducted by the Inter-African Bureau for Animal Health, more than 1,500 questionnaires fairly fully completed have been received at this Bureau since 1956, on cases which have been proved positive on laboratory examination. Of these, 132 have, during the period March 1956 to March 1960, related to species generally referred to as farm livestock.

A prescribed form approved by the Advisory Committee was put into use for the purposes of the survey by those countries participating, in which the first page of questions referred to clinical features of the case. The form was then posted to the laboratory at the same time as the specimen was forwarded for diagnosis. The reverse of the form applied to the laboratory examination which led up to a positive diagnosis.

The analysis of these returns has brought out much information of which the particular aspect of this communication was felt to be of general interest.

In the first instance Table I indicates the country of origin of the positive cases of rabies and the species infected. These figures referring only to positive cases diagnosed by laboratory techniques, cannot of course reflect the actual total number of cases which occurred in the same period since for many obvious reasons other positive cases were not brought to the stage of definite laboratory confirmation. Adamson (1954), for example, stated that in September 1951 in Southern Rhodesia for each laboratory-confirmed case of rabies in dogs, 14 were declared positive on clinical evidence alone.

The General World Incidence and Vectors

As a general impression of the world incidence of rabies in farm livestock and of the suspected or proven vectors, for comparison with Africa without an undue search of the literature, it can be stated that the incidence of the territorial distribution of rabies in the bovine host and in the lesser ruminants varies from nil to a number which poses a problem of some consequence.

In Latin America, thousands of cattle perish annually in areas where vaccination is not regularly carried out (Carneiro, 1954). The vector was discovered in 1911 to be the haematophagous bat which exists only in the American continent. Hidiroglou (1958) refers to the serious incidence of bovine rabies transmitted by vampire bats in French Guiana.

The animal health reports of the U.S.A. indicate an average of 1,000 deaths of cattle annually from rabies in that country.

TABLE I.—DISTRIBUTION OF CONFIRMED CASES OF RABIES IN FARM LIVESTOCK IN AFRICA 1956–1960

	Cattle	*Sheep*	*Goats*	*Donkeys Horses*	*Pigs*
Belgian Congo	15	1	1	3	4
Bechuanaland	–	–	1	–	–
Dahomey	–	1	–	–	–
Madagascar	3	–	–	–	–
Mozambique	1	–	–	–	–
Niger	–	–	–	1	–
Nigeria	–	–	1	1	–
Nyasaland	16	3	1	2	–
Rep. Cent. Africa	–	–	–	1	–
N. Rhodesia	7	1	1	1	1
S. Rhodesia	2	–	–	1	–
S. W. Africa	23	–	3	–	–
Tanganyika	2	–	–	–	–
Tchad	1	–	–	2	–
Union S. Africa	29	1	–	1	–
Totals	99	7	8	13	5

In Europe many countries reported an incidence. Nikolic and Jelesic (1956) record from Yugoslavia many cases of an atypical type of bovine rabies which was attributed to infection from insectivorous bats from the brains of which the causal virus was isolated. This type of bat was also incriminated as a vector of rabies in the U.S.A. and Germany.

In France, Verge, Saurat, Lautie and Goulard (1958), referring to the epizootic of rabies which had recently occurred in the south-west, state that 29 cases of bovine rabies were recorded of which 9 were confirmed by laboratory methods. In this outbreak the dog was regarded as the principal vector, but the feral carnivores were not excluded in spite of the fact that 16 foxes and 16 badgers, suspect, were proved negative.

In Germany from 1922–1925, 8,278 domestic livestock died of rabies or were slaughtered as suspected, of which 1,033 (12·5%) were cattle. In Schleswig Holstein from 1950–1953 during an epizootic of rabies where foxes seemed to be the principal vectors, 1,246 cases of rabies were recorded of which 12·4% were cattle.

In Spain between 1944 and 1953, 149 horses, 245 sheep, 99 goats, 85 pigs, and 10 mules and donkeys were proved rabid.

In Italy between 1946 and 1949, 7,061 individuals of the domestic livestock species were proved rabid. After prophylactic measures consisting principally of the vaccination of dogs, the total incidence in the period 1950 to 1953 dropped to 252 cases in the same group of animals.

In Africa, Curasson (1936) states that rabies was known in Madagascar since 1900 and that it was sometimes recorded in cattle. He refers to rabies in cattle in Algeria ascribed until 1925, when Donatien isolated the rabies virus from a case, to contagious encephalitis because of its atypical syndrome. He also records an epizootic of rabies in 1925 in the then Anglo-Egyptian Sudan in which cases occurred in cattle, horses and camels. From records available to the Bureau from the present Sudan Republic, which refer only to irregular periods in 1957 to 1959, positive rabies is reported in 4 horses, 19 donkeys, 6 goats and 1 sheep.

Rollinson (1956) has recorded that in Kenya in the period 1909 to 1952, 13 cases of bovine rabies were confirmed and that the jackal was the most important vector. From other sources of information on the wild life of Kenya, death in elephants has been attributed to rabies.

In the Union of South Africa from 1928 to 1952 positive rabies is recorded in the following hosts: 179 cattle, 1 sheep, 6 pigs, 7 horses and 5 donkeys (Snyman, 1953).

The Annual Report of the Veterinary Services of Nyasaland for 1958 records the positive infection of 9 cattle, 3 sheep and 1 goat. In none of these cases were there reports of the animals having been bitten and the clinical signs were in the first instance attributed to heartwater or cerebral piroplasmosis, conditions which were subsequently eliminated. When the salivary glands submitted for rabies examination were proved positive, the veterinarian involved in the clinical case had subsequently to receive a course of anti-rabies treatment. This indicates the risk involved in bovine rabies and the necessity for submission of salivary glands for laboratory examination. In all Africa, rabies of domestic livestock is known to both indigenous and non-indigenous stock owners.

In so far as vectors are concerned in the 99 bovine cases extracted from the 1,500 returns examined to date, in only 24 cases is there any mention of the vector. In the other cases this question has not been replied to or is recorded as unknown. Herds out grazing on ranches or in bush country often only under juvenile supervision may be bitten by a rabid carnivore with minor disturbance of the herd as a whole. Where a vector is specifically named in the above 24 cases the following animals are recorded: dog (15), jackal (3), ratel (2), leopard (1), hyena (1), mongoose (1), and an unrecognised wild animal (1).

In South Africa, Hennings (1948) states that the common wild vectors in that country are genets (*Genetta felina*), grey mongoose (*Herpetes pelverentus*), yellow mongoose or meer cat (*Cynctus penicillata*), suricate (*Suricata suricata*), squirrels (*Geosciurus capensis*), wild cats (*Microfelis negripes, felis ocreata*), skunks (*Ictinyz* spp.), ratels (*Mellivora capensis*), *Protels cristatus* and foxes (*Cynalopex chama*). Such animals during a rabies infection lose all fear of humans and human habitations and attack animals and man very readily. Children are frequently involved when catching quite easily such animals which, if normal, would avoid any attempt at capture.

In Nigeria, Thorne (1954) is of the opinion that the non-domestic carnivores constitute the most important source of infection for domestic livestock. Civets, genets, several species of mongoose, serval cats, wild cats, jackals and hyenas are known over most of the country. From 1944–1954, 1 bovine and 1 equine case

were diagnosed, and also 1 goat and 1 horse between 1956 and 1960. Earlier records also exist.

There is no record of insectivorous bats being incriminated in the transmission of rabies in Africa though these are exceedingly numerous in some areas, nor has the virus been isolated from them.

The natural transmission of rabies from one ruminant host to another by ticks is regarded by Bell, Burgodorfer and Moore (1957) as being unlikely though Reagan, Trombo, Geumlek and Brueckner (1956) successfully infected 12 hamsters by the intrarectal administration of an emulsion of ticks previously fed on artificially infected bats.

While not the subject for this paper the incidence of rabies in wild herbivorous ruminants is conspicuous by the absence of records. Only three cases in antelopes can be traced. It would be expected that closer contact with infected carnivores would render them more liable to be attacked though it is recognised that their ability to take evasive action is greater than that of the unsuspecting domestic herbivore.

Symptoms

The symptoms of rabies in herbivores have been well described in the classical literature, but further short descriptions have been more recently published. Hidiroglou (1958) in French Guiana describing paralytic rabies in cattle says that on the first day the animal shows impatience and is restive. On the second day there is trembling of the posterior limbs, urinary incontinence sometimes accompanied by salivation, on the third day the animal is unable to rise, the fourth day it is completely paralysed posteriorly and death ensues on the fifth.

In the Belgian Congo, Deom and Mortelmans (1954) referring to bovine rabies in Katanga amongst dairy cattle described the following symptoms : marked reduction of milk secretion, constipation, anorexia, marked salivation, rapid emaciation and an early comatose state. Sometimes the animal bellows and attacks or knocks its head against the walls if enclosed and death occurs generally about the fourth day after the appearance of symptoms.

More recently, Dundas Taylor (1959) described the disease in a calf aged 16 days in Nyasaland. On the first day this animal ceased sucking, salivated, and remained on its knees in the sucking position. There was constipation and while it retained the position for sucking it was incapable of doing so, and death occurred on the fourth day.

In 88 questionnaires which gave an indication of the syndrome out of the 99 bovine cases, 51 recorded a furious state and 37 a paralytic state but it would appear that these two types were not very distinct and that aggressiveness and paralysis often co-existed.

The sex of the animal did not appear to be of any consequence in spite of the fact that 20% of the cases were males and 80% were females. These figures would roughly correspond to the percentage of the two sexes in an average herd. The age of the case did not appear to be significant: 16 per cent under 1 year, 16 per cent between 1 and 2 years, 16 per cent between 2 and 3 years, 12 per cent between 3 and 4 years, 11 per cent between 4 and 5 years and 29 per cent over five years of age.

On account of the difficulty of obtaining the data little mention was made in the questionnaires of the incubation period but it would appear that it does not vary greatly from that in other species and is recorded as between 5 and 6 weeks. However, a short incubation of a few days in one case and a long incubation of 5 months in another were recorded.

Death would appear to occur generally on the third or fourth day after the appearance of symptoms, but records of 48 hours only and as long as 12 days were noted. Death may occur suddenly immediately following an aggressive crisis or without noticeable signs following a period of coma.

The questionnaires which concerned ovine and caprine cases were too few for the purpose of an analysis, but a good description of an outbreak of rabies in a flock of sheep in Southern Rhodesia is described by Darbyshire (1953). In this outbreak the vector was a ratel (*Mellivora capensis*), the incubation period about 20 days and the symptoms included excitability, aggressiveness towards other members of the flock, marked salivation, abnormal sexual behaviour, dyspnoea, paralysis and death.

In 11 cases of equine rabies of the thirteen recorded the syndrome was recorded as furious. The symptoms in sequence were excitability, trembling, colic, hydrophobia, ataxia and severe pruritis resulting in self-mutilation. The animal frequently destroyed its stable. Death appeared to occur comparatively quickly after the appearance of symptoms, even as early as five hours and very frequently within 48 hours.

Laboratory Examination of Suspected Material

Again referring to only the 99 cases of bovine rabies under reference which have been analysed, Table II indicates the results obtained from the histopathological, and biological examinations made.

Table II.—Laboratory Examinations of Suspect Material

Clinical Syndrome	*Histopathological Examination*						*Biological Examination*					
	Section			Smear			Brain			Salivary Glands		
	+	−	Total	+	−	Total	+	−	Total	+	−	Total
Furious	39	9	48	1	0	1	40	0	40	4	1	5
Dumb	29	6	35	1	0	1	22	0	22	1	0	1
Not stated	11	2	13	0	1	1	9	0	9	0	0	0
Totals	79	17	96	2	1	3	71	0	71	5	1	6

It will be noted from Table II that the biological examination of cerebral material gave a positive result in every case in which it was undertaken. Further, the percentage of positive histological examinations, 80 per cent, was very much higher than generally described in the literature which usually admits to as low a percentage as 50 per cent of detection of Negri bodies in the brains of rabid cattle.

In Table III a comparison is made of the results obtained from the different methods of examination practised on material from one animal.

TABLE III.—COMPARISON OF TESTS BETWEEN BRAIN AND SALIVARY GLANDS

Brain		*Salivary Glands*	*Number of Cases*
Negri Bodies	Virus	Virus	
+	+	No biological test	47
−	+	No biological test	16
+	+	+	4
+	+	−	1
−	+	+	1
+	−	No biological test	28
−	+	No biological test	2

It is unfortunate that so few cases were submitted to a biological test of the salivary glands.

It is interesting to record that of the 98 cases in which the state of preservation of the specimen was stated, 41 are recorded as being either decomposed or badly preserved, yet examination could be carried out with the above-mentioned highly satisfactory results.

PROPHYLAXIS

In none of the 99 cases under review had the cattle been previously vaccinated. This reflects the fact that the vaccination of cattle against rabies is not often practised in Africa and indeed as a standard procedure it is rarely justified.

In America thousands of cattle have been vaccinated over the last 25 years and there is a considerable literature on the methods which should be adopted.

The Expert Committee on Rabies of the World Health Organisation has met from time to time over the last 10 years including a meeting late in 1959. The recommendations of such an expert body must be regarded as the best advice available and in respect of cattle vaccination the recommendation is that either the virus vaccine Flury H.E.P. or the virus vaccine Kelev, or inactivated vaccines may be used for the protection of cattle.

The Flury H.E.P. virus vaccine should be inoculated intra-muscularly in the thigh using a minimum dose of 3 ml. of a 33 per cent suspension of tissue. The Kelev virus vaccine should be administered by the same route in a minimum dose of 6 ml. of a 66 per cent suspension. While the single dose of vaccine provokes the formation in a majority of animals of a sufficient quantity of antibodies for protection, a second dose 30 days later is recommended to reinforce the immunity which, as far as experimentation has gone, lasts at least one year and probably longer.

The inactivated vaccines should be used in the same manner, utilising 30 ml. of a 33 per cent suspension of tissue.

As regards the measures to be taken where livestock have been bitten by a confirmed vector the recommendations are less precise. It has been stated that domestic herbivores do not propagate rabies, but there are reports of such animals having bitten humans who subsequently developed the disease. The W.H.O. expert

committee state that in the case of a meat-producing animal the flesh may be consumed during the following week after exposure, or six months afterwards. The danger from such an animal is rather to those handling such meat than to those who eat it. As far as treatment is concerned the committee cannot be definite since little experimentation has been carried out.

The passage of rabies virus through the milk in both natural and experimental infections does not seem to have been the object of any study since Remlinger and Bailly (1932), who confined their work to dogs, cats and guinea-pigs. The results of these experiments indicate that the milk taken immediately prior to death only exceptionally contains the virus. Taking this into consideration and the fact that milk secretion almost ceases during the syndrome, the likelihood of infection through this medium appears to be remote.

However, it would appear to be indicated that experiments with the milk of artificially infected cattle, sheep and goats should be carried out to confirm that the virus is not present before the first symptoms, as in the case of the saliva and therefore while the animal is in full production of milk.

Summary

A short review is made of rabies of domestic livestock with special reference to Africa from the records made available to this Bureau on confirmed cases of rabies during the period 1956–1960.

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OBSERVATIONS ON THE INCIDENCE, PATHOLOGY AND AETIOLOGY OF *SPIROCERCA LUPI* INFESTATION IN NYASALAND

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INTRODUCTION

Spirocerca lupi (Rudolphi, 1819) is a spirurid nematode, parasitic in the dog, fox, jackal and wolf, which is found in the walls of the oesophagus, stomach and dorsal aorta. It also occurs much more rarely in lungs, bronchi, lymphatic system or attached in the thoracic and abdominal cavities. The adult parasites, which are red in colour and from 30 to 80 mm. long, produce, and live in, tumours which contain cavities filled with a milky fluid. According to Neveu-Lemaire (1936) each tumour can harbour from one to fifty or even a hundred worms, but in these observations the number was seldom less than six or more than twelve. There is usually a small opening which affords communication between the cavities of the tumour and the lumen of the oesophagus. Through this the female extrudes herself to lay her eggs. This worm is the cause of various types of illness which may be fatal to the host.

The life-cycle requires an intermediate host for its completion and, in addition, various secondary intermediate hosts play an important rôle in dissemination. The essential intermediate host is a coprophagous beetle in which the *Spirocerca* eggs hatch, develop to the third or infective stage, and then remain encysted. If the beetle is swallowed by a dog or other suitable host the larvae continue their development and finally reach the adult stage in one of the predilection sites. If, on the other hand, the beetle is swallowed by an unsuitable host such as a frog, lizard, bird or insectivorous mammal, the third stage larvae, released from the beetle, merely re-encyst in the mesentery or the alimentary canal and resume their wait in the hope that this transport host will one day, in turn, be eaten by an appropriate definitive host.

Although this worm has been reported from a fox in Norway (Svenkerud, 1947) it is usually only found in the warmer latitudes in which it has a world-wide distribution. Reports of incidence vary from different countries and are as follows: 10 per cent in dogs from Japan (Neveu-Lemaire, 1936); 20 per cent in South Africa (Kaschula & Malherbe, 1954); 25 per cent in China (Hsu, 1948); 40 to 50 per cent in Indonesia (Kraneveld & Djaenoedin, 1952); 42 per cent in India, 70 to 90 per cent in Algeria and practically 100 per cent in Southern Tunisia (Neveu-Lemaire, 1936).

Incidence in Nyasaland

1. *Rural:* In the Southern Province of Nyasaland *post-mortem* examinations were conducted on 120 indigenous village dogs within a radius of some 40 miles. These dogs had been destroyed in the course of an anti-rabies campaign and were typical representatives of the Nyasaland native dog which is a distinct type and appears to have crossed very little or not at all with foreign breeds. It is a member of the domestic community typical of rural village settlements throughout the country. The survey revealed the remarkably high incidence of 100 per cent. *Spirocerca lupi* infestations in adult dogs. Since the time of this survey (May, 1957), about twelve native dogs from similar communities in other areas of the Southern Province sent to the laboratory for post-mortem examination have all been infested with this worm. Thus the high incidence would appear to be widespread in the southern part of the territory at least.

2. *Urban:* Of 54 European-owned dogs, mostly exotic breeds, from the town and suburbs of Blantyre, examined *post mortem*, in the course of the past two years, only four have been found to be infested with *Spirocerca lupi*.

History, Symptoms and Post-mortem Findings in some Cases of Malignant Spirocercosis

Case No. 1. A spaniel was presented at the Blantyre clinic one morning in a somewhat depressed state. The symptoms were a mild degree of dyspnoea and paler than normal mucous membranes. The temperature was 103° F. Percussion revealed an area of reduced resonance in the lower part of the chest. A blood smear was negative on examination for *Babesia*. A tentative diagnosis of thoracic infection was made and the patient treated with penicillin. On the afternoon of the same day respiratory distress suddenly became acute and within approximately five minutes the dog collapsed and died. At this stage the mucous membranes had become almost white.

Post-mortem Findings: When the thoracic cavity was opened it was found to be almost completely filled with blood. The patient had literally bled to death within its own thorax. There was one *Spirocerca* nodule on the wall of the oesophagus some four inches anterior to the diaphragm, which appeared to be normal. A second nodule was found on the wall of the aorta about two inches posterior to the origin. The aorta was ruptured at the edge of the tumour at a point where it had become necrotic. Symptoms had obviously started with a slight leakage and the condition rapidly reached a fatal culmination when the weakened aortic wall suddenly gave way.

Case No. 2. A terrier-type dog was brought to the clinic with the history of a chronic cough and recent onset of vomiting. The latter symptom had started three or four days previously and had become steadily worse until at the time of presentation of the dog at the clinic it occurred twice within twenty minutes. The *vomitus* had the appearance of pure blood. A smear was made from a drop of it, stained, and shown to be indeed almost pure blood. A tentative diagnosis of spirocercosis was made, the vomiting treated symptomatically, and

the dog placed under observation. Early the following morning it was found dead, surrounded by a pool of blood.

Post-mortem Findings: In the thoracic part of the oesophagus, about four inches anterior to the diaphragm, there was a walnut-sized *Spirocerca* nodule. When the lumen of the oesophagus was opened it was found to contain a clot of blood which extended into the stomach. The *Spirocerca* nodule itself, when opened, was found to be haemorrhagic. This patient had slowly bled to death into its own alimentary canal.

Case No. 3. A villager had had his dog (a pregnant bitch in poor condition) vaccinated against rabies on a Monday morning. The animal died the following Wednesday night. Next day he called at the Provincial Veterinary Headquarters with the complaint that his dog had died as a result of the vaccination. It was difficult to obtain a clear picture of the clinical symptoms from him and all that could be ascertained was that there had been considerable respiratory distress a short time before death.

Post-mortem Findings: Autopsy revealed the most extensive infestation with *Spirocerca lupi* seen in the course of these observations. There were no less than seven nodules, some of very great size, distributed as follows: four on the oesophagus at the usual site near the level of the heart; three on the aorta in the lumbar region. Two of these were the size of a hen's egg and one the size of a walnut. The aorta immediately anterior to these tumours was enormously dilated and it is considered probable that death was due to thrombosis arising from this aneurysm, but this, unfortunately, could not be confirmed since decomposition was too advanced for satisfactory histological examination.

Local Aetiology

Dung beetles of many varieties abound in the rural village areas and are particularly abundant during the rainy season. Protein-hungry village dogs will eagerly devour these intermediate hosts of *Spirocerca lupi* as well as lizards, small insectivores and especially poultry and francolins which act as transport hosts. Many villagers will not eat the viscera of poultry but feed them raw to their dogs. The perimeters of many Nyasa villages are haunted by packs of ownerless dogs which prey on the free-ranging village poultry and on the francolins common in the maize lands adjacent to villages. It is considered that the main sources of infection for pet and sporting dogs are (a) the feeding of offal from village poultry purchased at the town markets; (b) the feeding of offal from francolins brought home from game-shoots; (c) the depraved appetite of some pet dogs which induces them to eat evil-smelling dung-beetles (scarabs); and (d) the sporting instinct in certain breeds which causes them to chase and eat the common lizards (skinks) which abound everywhere. Village poultry purchased at the Blantyre town market have frequently been found to carry encysted third-stage larvae and these must be regarded as the main source of infection, since infected beetles and lizards are only likely to be encountered on walks through rural areas.

SUMMARY

A brief introductory review of our knowledge of *Spirocerca lupi* is followed by a report on its incidence in the Southern Province of Nyasaland, descriptions of three fatal cases of spirocercosis, and a note on local aetiology and its bearing on prevention of infection in pet animals.

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TRANSIENT ELEMENTS OF THE SHEEP SKELETON

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The living ungulates have advanced in economy of skeletal structures to the state where several bones found in primitive forms are found today only in a reduced state, if present at all. In the fore-limb the clavicle is virtually dispensed with and in the hind limb the fibula bears little weight and tends to undergo reduction. The development of the ungulate foot has been accompanied by a reduction in size and an elimination of some of the digits ; the first digit must have been lost very early and a four-toed *manus* and *pes* were characteristic of forms as dissimilar as ancestral horses and cows (Romer, 1949). Further reduction followed two different paths. In the artiodactyla the axis of the limb passed down between the third and fourth digits which then became the dominant members, while digits two and five tended to be less pronounced. In the perissodactyla, digit three became the weight-bearer. The carpus and tarsus may have undergone consolidation and fusion. In the fore-limb the second and third carpal bones of the distal row may form one unit and in the hind limb the second and third tarsals of the lower row may fuse and so also may the central and fourth tarsals.

The adult sheep skeleton has no clavicle and only a distal epiphysis of a fibula, which is known as the malleolar bone. It shows fusion of some carpal bones, fusion of some tarsal bones, and has, at the best, vestigial second and fifth metacarpals and metatarsals. It has been noticed, in studying the development of the sheep skeleton, that the foetus has rather more of these structures than the adult and it would appear that the foetal sheep is not so far removed from its forebears as the adult stage would suggest. As these bones appear at some stage or other as separate and independent elements of the skeleton before their removal, atrophy, or fusion, they have been termed here transient elements.

Materials and Methods

The data presented in this paper are based on the materials used for a much wider work (Smith, 1955). For the latter, 320 sheep foetuses at all stages of development were X-rayed and 101 sheep foetuses were also prepared by the alizarin staining technique which stains the calcium-containing parts of the body whilst rendering the remainder translucent. Histological examinations of embryos of 28, 35, 38, 40, 48, 65, and 148 mm. crown-rump length were carried out. Many of the flock of Clun sheep kept at the Veterinary Field Station of the University were X-rayed at regular intervals and certain lambs of known ages were also X-rayed after dissection. To establish the frequency of the small metacarpals and metatarsals the distal parts of all the limbs of 168 sheep were obtained from local slaughterhouses and X-rayed.

PLATE I

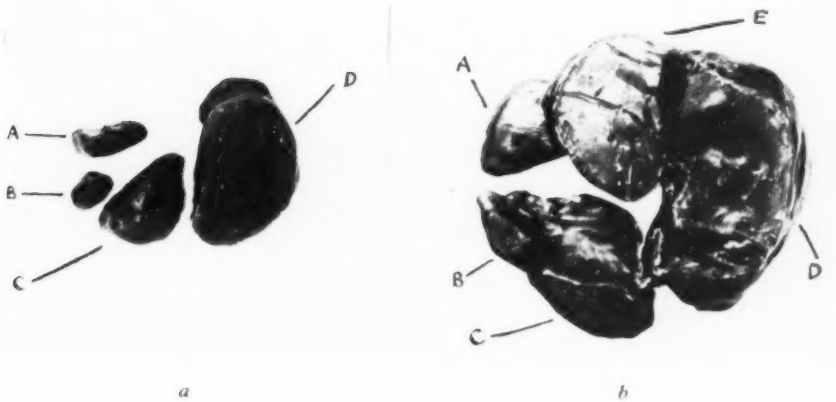


FIG. 1

Wax reconstructions of part of the tarsus of sheep foetuses of the following crown-rump lengths: (*a*) 38 mm. (*b*) 48 mm. A: first tarsal. B: second tarsal. C: third tarsal. D: fourth tarsal. E: central tarsal. In (*b*) the cartilage primordia of the second and third tarsal bones have fused.

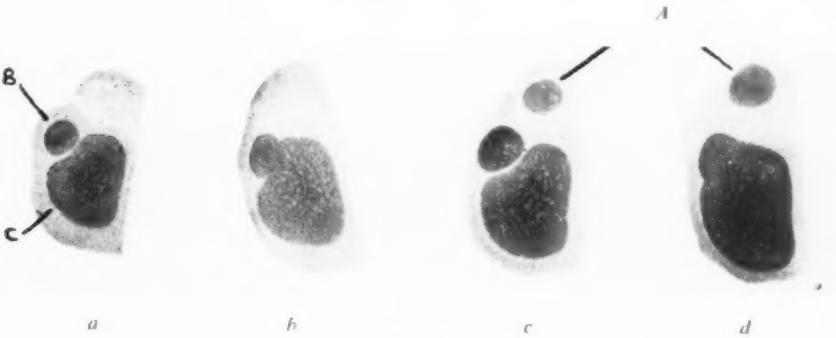
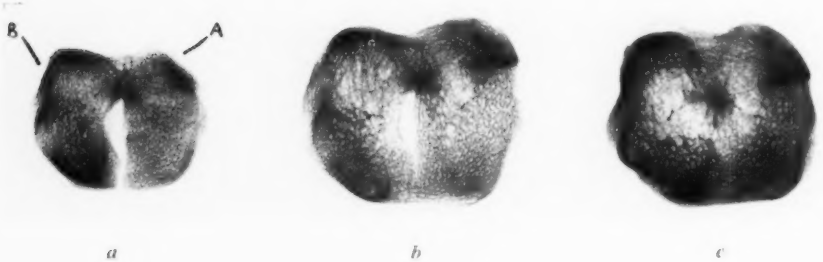


FIG. 2

Radiographs of part of the tarsus of foetuses of the following crown-rump lengths: (*a*) 460 mm. (*b*) 490 mm. (*c*) 490 mm. (*d*) 510 mm. A: first tarsal. B: second tarsal. C: third tarsal. The fourth tarsal has been removed. The sequence shows fusion of the second and third tarsal bones; in (b) fusion occurs before the first tarsal centre appears, in (c) after.

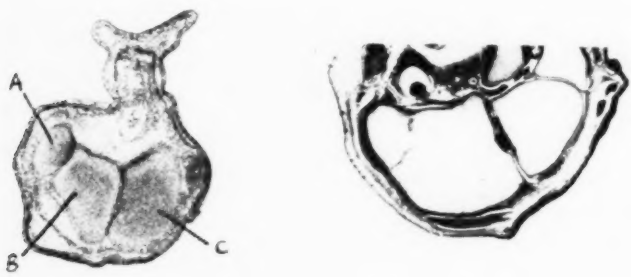
PLATE II



a *b* *c*

FIG. 3

Radiographs of part of the tarsus of post-natal lambs. (*a*) at 2 months. (*b*) at 5 months. (*c*) at 8 months. A: central tarsal bone. B: fourth tarsal bone. The central and fourth tarsal bones fuse along the plantar edge in (*a*), plantar and dorsal edge in (*b*), and completely in (*c*).



a *b*

FIG. 4

Histological sections of the carpus of foetuses showing the carpal bones as cartilage primordia. (*a*) 40 mm. crown-rump length. (*b*) 148 mm. crown-rump length. A: second carpal. B: third carpal. C: fourth carpal. In (*a*) the cartilage primordia of these three elements are separate: in (*b*) the second and third primordia have fused.

a *b*

FIG. 5

Radiographs of part of the carpus of (*a*) 470 mm. crown-rump length foetus, (*b*) four month post-natal lamb. A: second carpal bone. B: third carpal bone. C: fourth carpal bone. The second and third carpal bones, separate in the foetus, have fused in the lamb.

OBSERVATIONS

Metacarpals

There is some uncertainty as to whether the second and fifth metacarpals appear in the adult sheep more often than to constitute something very unusual. The limbs of 168 sheep were examined radiographically to see how often these small metacarpals occurred (Smith, 1956a). Second metacarpals were found in about eight per cent of the limbs examined. These bones were not at all complete, their average length was 2.5 cm., while the average length of the third and fourth metacarpals was 13 cm. Fifth metacarpals were found in about ninety per cent of the limbs. The length of the fifth metacarpals averaged about 4.5 cm.

In foetuses of about 30 mm. crown-rump length the second, third, fourth and fifth metacarpals all appeared in cartilage. The second and fifth were much smaller in cross-section than the third and fourth and also did not extend to the full length of their larger neighbours. Ossification of the minor elements took place very soon after that of the major metacarpals, at about 60 mm. crown-rump length, and the four metacarpals could be seen as separate and partly ossified rods. In alizarin preparations the second metacarpal was found in all 67 specimens examined between 65 and 250 mm. crown-rump length. In the 21 above this size it appeared in only ten. The fifth metacarpal was found in all but one of 88 alizarin preparations above 65 mm. crown-rump length.

Metatarsals

Out of the 168 adult sheep examined not one showed either a second or a fifth metatarsal. There is a small nodule of bone to be found on the plantar aspect of the metatarsal region, embedded in the interosseus medius muscle, or suspensory ligament. It is sometimes suggested that this is the second metatarsal, but it has been shown that this cannot be so (Smith, 1956b).

Cartilaginous second, third, fourth and fifth metatarsals were, however, present in early embryos, ossifying at about the same time as the corresponding metacarpals. The second and fifth metatarsals were not as constant as the second and fifth metacarpals and after 175 mm. crown-rump length their frequency in alizarin preparations rapidly declined. Second metatarsals were present in 39 out of 44 foetuses between 65 and 175 mm. and in six out of 44 above this size. The fifth metatarsal presented a similar picture. It was present in 40 out of 44 below 170 mm. and in ten out of 44 above this size.

Tarsal bones

In early embryos (about 40 mm. crown-rump length) cartilaginous precursors were present for the first, second, third and fourth tarsal bones of the distal row (Fig. 1*a*). Very soon (48 mm. crown-rump length) the second and third began to fuse (Fig. 1*b*) and by 65 mm. crown-rump length they formed one block. Later in development an ossification centre appeared in each of the four original cartilaginous tarsal bones, in the fourth at about 250 mm., the third at 280 mm., the second at 380 mm. and in the first at about 400 mm. crown-rump length.

Radiographs of a 460 mm. crown-rump length foetus showed the second and third tarsal centre still separate (Fig. 2*a*). Sometimes the second and third fused

before the first appeared (Fig. 2*b*) or the first appeared and then fusion occurred (Fig. 2 *c*). In any case fusion of the second and third tarsal bones occurred before birth (Fig. 2*d*).

The central tarsal also appeared as a cartilaginous entity in early embryos but fusion with the fourth tarsal soon took place. The centre of ossification for the central tarsal appeared fairly early, before those in the distal row. At birth these centres were still separate, at two months some fusion had occurred along the plantar edge, at five months along the dorsal and plantar edges and by eight months complete fusion had occurred (Fig. 3*a*, *b* and *c*).

Carpal bones

It would be convenient to say that there were four bones in the distal carpal row but unfortunately there was no sign of a first carpal. In embryos of about 40 mm. crown-rump length the second, third and fourth were present as separate areas of cartilage (Fig. 4*a*). By about 140 mm. crown-rump length the second and third had fused (Fig. 4*b*). Three centres of ossification occurred, for the fourth carpal by about 250 mm., third carpal 275 mm., and second carpal 400 mm. crown-rump length. Radiographs of a typical embryo of about 470 mm. crown-rump length showed all three centres separate (Fig. 5*a*). Fusion had not taken place before birth but it had occurred by about four months, although the origins of the bones could still be seen (Fig. 5*b*). Later, this distinction disappeared.

Fibula

In the adult sheep this bone is usually considered to be represented only by the malleolus at the distal end of the tibia and the ligament stretching from this to the proximal end of the tibia. In old sheep calcification and even ossification of this ligament may take place, but this is a secondary occurrence.

In foetuses a full-length cartilaginous fibula was present and ossification of the shaft began at about the same time as that of the tibia. This was at about 35 mm. crown-rump length. As the foetuses grew larger the shaft of the fibula became attenuated and then appeared to become so thin as to disappear, leaving only the fibrous ligament. At approximately 150 mm. crown-rump length the cartilaginous proximal end of the fibula merged into the cartilaginous end of the tibia, but the distal end retained its independence. From about 480 mm. crown-rump length this distal end ossified. Here then is a bone which appears as a full-length cartilage model, ossifying at all but the proximal end but usually retaining only the distal end. In the sheep, this distal end articulates with the tarsus and no doubt plays some subtle part in the mechanics of the joint.

Clavicle

The first centre of ossification which appeared in the appendicular skeleton occurred in a 26 mm. crown-rump length embryo. It was a small paired centre in front of the thorax and below the vertebral column. However, this bone tissue had been completely removed by 50 mm. and thereafter there was no trace of osseous material. Besides this absorption of the bone it is also interesting that neither cartilage nor cartilage-like tissue appeared as is found with the human clavicle. In fact, the first indication was a condensation of mesenchymal cells which enlarged

and became osteogenic. When bone was laid down it appeared as a system of trabeculae in the intercellular matrix. The lack of cartilage is, of course, consonant with the origin of this bone as a dermal derivative.

Discussion

Examination of foetal and adult sheep shows that four metacarpals and four metatarsals always appear and ossify. The second and fifth metacarpals may persist but in a greatly reduced state, but the corresponding metatarsals are removed. Separate cartilaginous primordia appear for each of the carpal and tarsal bones represented in the adult and while still in this state some fusion takes place. Separate ossification centres then appear for each of the primordia and fusion of these centres occurs later. The fibula appears as a complete cartilaginous model, the shaft and distal epiphysis ossify but the cartilaginous proximal end merges with the tibia. The ossified shaft is usually removed leaving only a ligament, but the ossified distal epiphysis persists. The clavicle appears as a bony element and disappears very quickly.

These then are the transient elements. But why should they always appear? It is tempting to invoke Haeckel's Biogenic Law that " ontogeny is the short and rapid recapitulation of phylogeny " and describe the sheep as metaphorically climbing up its own family tree. Here we have a clavicle, which it has been suggested was last seen in adult ungulates when Typotheria inhabited the earth (Harris, 1936), and four metacarpals and four metatarsals of nearly the same antiquity. A fibula almost completes a ' typical ancestral ungulate ' so that it would seem that the only thing a sheep has really lost is the first carpal bone.

However, this idea of " family tree climbing " is not now acceptable (see de Beer, 1958, for a discussion of the rejection of the theory of recapitulation) and we must look elsewhere for the cause of the constant appearance of these transient elements. *It seems likely that all these elements always appear because they are necessary for proper development of the foetus.* Although the adult can dispense with these structures, it does not follow that the foetus is able to. It may well be that they are landmarks necessary for normal development of the adjacent tissues. In the carpal region, for instance, both foetus and adult can dispense with a first carpal bone and so it does not appear. The adult, not needing side to side or rotatory movement of its lower limbs, can survive with two blocks of bone. Then why not develop only two? The fact that three are developed originally can perhaps be explained on the grounds that at some time the foetus needs three units. The region is designed, perhaps, so that adjacent structures can only develop correctly if there are three, or *vice versa*, adjacent structures will only allow carpal development if there are three. Perhaps the blood supply of the carpus is designed to form three centres of ossification and to be incapable of supplying two centres sufficiently well to replace the original three.

The clavicle may well have to appear for proper development of the brachiocephalic muscle. It is known that this muscle can be divided into that region from the arm to the clavicle area and another region from this area to the head and neck. If there were no clavicle in the foetus it might be that this muscle would not develop properly. The fibula, unnecessary in the adult as a functional unit, in the

foetus may well be essential for development of muscles which later require only a fibrous mass as attachment, or muscles which by later amalgamation can transfer their origins to other bones such as the tibia. Perhaps blood vessels, nerves, etc., also need these elements to give accurate landmarks for their development.

When their work as scaffolds, stimulators or landmarks is completed and the adjacent structures are orientated correctly, their own development alters. In some cases, fusion to adjacent structures occurs — as has been described for the upper end of the fibula ; in others, such as the metacarpals, incomplete removal both in quantity or number takes place, leaving them sometimes present, sometimes absent, and occasionally complete removal occurs, for example, the clavicle. Perhaps this degree of removal is related to the effect they will have on adult life. One could imagine that those which are completely removed are those which would inconvenience the adult and those which are inconstant are ones that do not affect the developed adult. There are, of course, anomalies occasionally when one of the transient elements continues to develop and resists removal.

Wood Jones (1953) has suggested that a rather more profitable way of regarding embryonic phases of development may be that of recognising them as developments directed towards the satisfaction of embryonic needs than as rehearsals of supposed ancestral stages. The observations described here suggest that it is possible to go further and say that structures similar to the ones mentioned are present not simply to show that the free living animal of long ago found them useful, but because the developing animal of today finds them essential.

Summary

Several parts of the skeleton which ossify as separate elements in foetal life either disappear or fuse with other structures during later development. The second and fifth metacarpals may persist, but are greatly reduced while the corresponding metatarsals are completely removed. The clavicle also disappears after appearing as a bony structure and most of the fibula disappears. Many of the carpal and tarsal bones ossify as separate elements which later fuse.

It is suggested that all these structures must appear as separate elements for the proper development of the foetus. When their work is accomplished the structures may then be removed, in part or completely, or lose their identity by fusing with neighbouring structures.

Acknowledgments

I would like to thank Dr. E. H. Batten and Miss P. Morgan for assistance with the histology and Mr. A. Coombs for the photographs. I am also very grateful to my colleagues for discussions on many features of this work.

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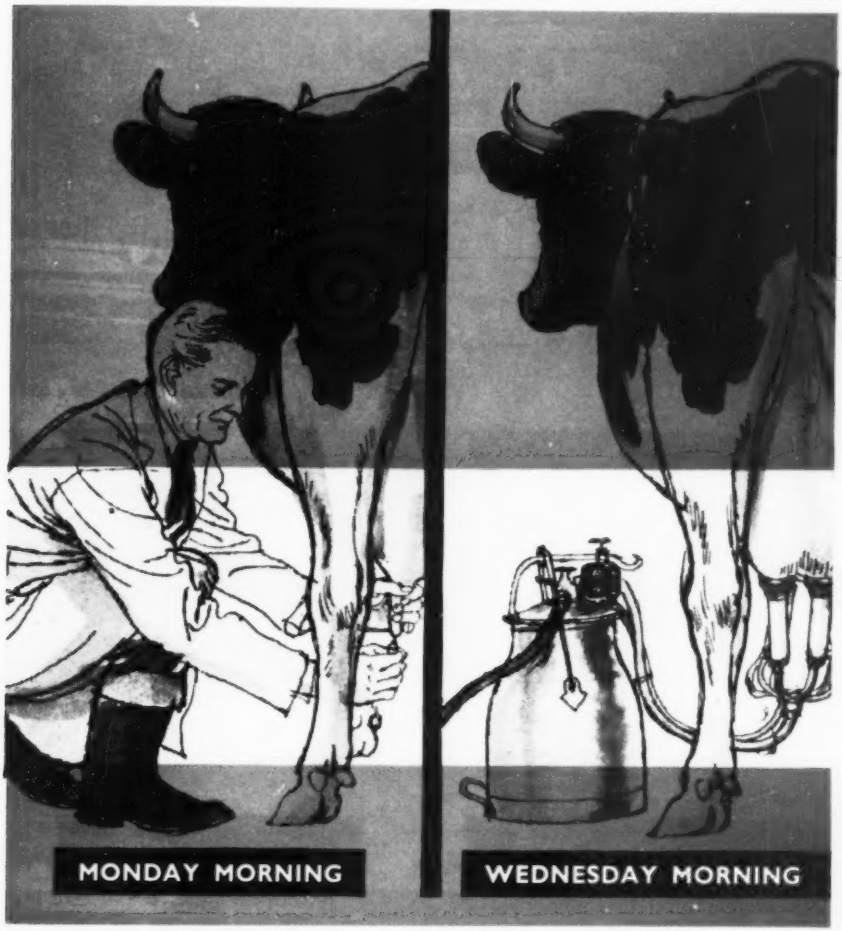

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4	305	0.29	334	0.53
6	441	0.25	475	0.47

* *Liver Vitamin B12 not estimated.*

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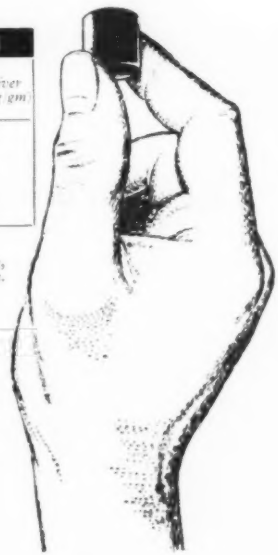

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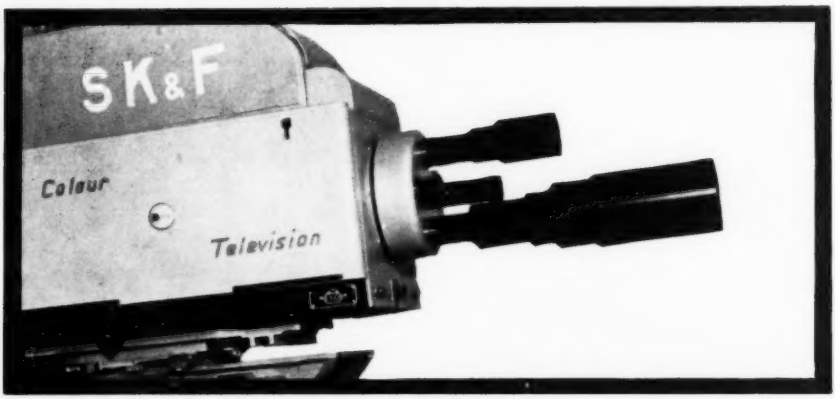

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THE NEMATODE GENUS *STRONGYLOIDES GRASSI*, 1879 IN INDIAN LIVESTOCK. I : OBSERVATIONS ON NATURAL INFECTIONS IN THE DONKEY (*EQUUS ASINUS*)

By B. P. PANDE and P. RAI

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The genus *Strongyloides*, extensively studied by a number of workers, enjoys a wide host-range and is cosmopolitan. Amongst the nematodes, it is unique because it has two distinct generations in its life-cycle and is characterized by a marked pathogenicity exhibited by the parasitic female in a large number of hosts. The most notable work done so far is with regard to its type species, *S. stercoralis* (Bavay, 1876, Stiles and Hassal, 1902) which is the cause of strongyloidosis in man—a disease prevalent in South-East Asia, parts of Africa and Tropical America and discussed by Faust (1949) and Chandler (1955). According to Goodey (1926), this species occurs naturally in man and dog while according to Faust (1949) the human strain can be successfully implanted in dogs for several months but finally dies out. Chandler (1955), however, observes that *S. stercoralis* is infective for dogs and cats as well as man but usually dies out in a number of weeks. A large number of related species have been recorded from primates and other mammals and the lower vertebrates as well. Chandler (1925) and Sandground (1925) had pointed to the great confusion in the matter of specific conception under this genus and also critically reviewed the previous work. Goodey (1926) believed that certain well-defined species could be recognized but some of these either naturally or experimentally could parasitize more than one host.

Without attempting a discussion on the question of validity of the various species, it may only be mentioned that even to this day any systematic differentiation in this genus continues to remain confused evidently because of incomplete considerations, in the specific concepts, of both the free-living and parasitic stage, which provides only a limited scope in affording reliably constant morphological differences, and the non-availability of details regarding its biology in infections encountered in the host species, particularly in the domestic animals. This can only be possible if and when fuller information including results of cross-infections administered experimentally accumulates. Till then the question of classification and validity of some of the species assigned to this genus would continue to remain unsolved. The first complete account with clinical signs and tissue damage in strongyloidosis in experimental single infection of *S. papillosus* given to sheep and goats has recently been given by Turner (1959).

Yorke and Maplestone (1926) listed the five species *S. canis* (Brumpt, 1922) in dog (synonymized by some with *S. stercoralis*) ; *S. papillosus* (Wedl, 1856, Ramsom, 1911) in sheep and goats, subsequently reported from rabbit, rat, pig and ox; *S. suis* (Lutz, 1894, Linstow, 1905) in cattle and pig ; *S. vituli* (Brumpt, 1921) in cattle and *S. westeri* (Ihle, 1917) in horse and subsequently from pig also. Baylis (1929) considered that the species occurring in man and domesticated animals were at least three, viz. *S. stercoralis*, *S. papillosus* and *S. westeri* of which he gave measurements for both parasitic females and the free-living forms in the first two and only for the parasitic stage in the last one. Chandler (1925) stated that the bisexual generation in this species had also been found by Blick and Bandet who had failed to infect a dog with a large number of the filariform larvae of *S. westeri*. The names of the other species that have so far been reported from livestock are : *S. stercoralis* var. *felis* (Chandler, 1925) from cat, *S. avium* (Cram, 1929) from fowls and turkeys (Morgan and Hawkins, 1953), *S. cati* (Rogers, 1939) from cat and *S. tumefaciens* (Price and Dickman, 1941) from dog and cat. The species of *Strongyloides* so far known from Indian livestock are *S. stercoralis* (Bhalerao, 1935, Baylis, 1936), *S. felis* (Chandler, 1925), *S. papillosus* (Baylis, 1936, Mudaliar and Alwar, 1947) and *S. avium* (Ramanujachari and Alwar, 1954). Chandler (1955) has observed that he had found a high percentage of cats in India naturally infected with a form of *Strongyloides* which was very similar to, if not identical with, the human species. The present communication records for the first time *S. westeri* infection in the donkey (*Equus asinus*) and is also the first report of an equine host in India.

A large number of parasitic female worms, collected at *post-mortem* examination on two occasions from the duodenum, were found attached to or embedded in the crypts and villi of the mucous membrane, which was red in colour with evidence of petecheal haemorrhage. The donkeys were less than one year in age (one was reported to be about nine months old).

The specimens agreed with the measurements given by Baylis (1929). The positions of oesophagus and the nerve-ring were found to be 1·03–1·5 mm. and 0·3–0·4 mm. from the anterior end respectively. The tail measured 0·06–0·1 mm. and the vulva was situated 2·4–3·4 mm. from the posterior end. The fully embryonated eggs, obtained from females left in culture, measured 0·052–0·054 × 0·043–0·044 mm. and the first stage larva, that had hatched, measured 0·28–0·3 mm. in length. The eggs, seen in masses inside the tunnels made by the females in the mucosa, were all in the segmented stage in the large number of sections examined. Embryonation presumably takes place later in the gut lumen.

Strongyloides in foals has been recorded by a number of workers and young foals, infected soon after birth, have been reported to show digestive disturbances as a result of the injury done to the mucous membrane. Hutyra and Marek (1946) state, " the worms appear to exert pathological action in very young animals only but according to Wester older colts and adult horses are immune against *Strongyloides* invasion and other observers have found *Strongyloides* worms present in adult swine and horses without any disturbance of health (worm carriers). In young foals infected soon after birth the larvae produce digestive and nutritional disturbances by injuring the mucous membrane of the intestine which they also render liable to secondary infections ". According to Lapage (1956), *S. westeri* is found chiefly in foals and may

PLATE III

FIG. 1. Photomicrograph of a portion of duodenal wall showing a section of a worm in the mucosa. H & E. ×140.

cause diarrhoea; he quotes Russel and Todd *et al.* who held that foals develop a resistance at the age of 15–23 weeks and that the infection then disappears. This view is definitely against the observations recorded herein as in both the cases the animals were found somewhat emaciated and a study of the stained serial sections revealed considerable desquamation of the epithelial lining, a marked congestion of the mucous membrane consequent upon the presence of the worms which are surrounded by an exudate consisting chiefly of desquamated epithelial cells, lymphocytes, plasma cells, neutrophiles and a few macrophages and eosinophiles. Red blood cells could be observed in the tissues, around the worms, with striking changes in the surface epithelium which was eroded—some of the affected portion was flattened but mostly it was in a desquamated condition. There was no change in the muscularis mucosa and the Brunner's glands but the submucosa was congested with dilatation of its veins which were full of red blood cells and a few eosinophiles were also present. Evidence of haemorrhage at a few points was clearly visible. All these changes were suggestive of a subacute type of inflammation.

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SUMMARY

The present position regarding classification in the nematode genus *Strongyloides* has been outlined. To host records for the species reported from domestic animals, the donkey is added as a host of *S. westeri* and this is the first record of this genus in an Indian equine host. Pathogenic effects in the two cases studied have been described.

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LOUPING-ILL :

THE RED DEER (*CERVUS ELAPHUS*) AS AN ALTERNATIVE HOST OF THE VIRUS IN SCOTLAND

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The possibility that alternative hosts of louping-ill virus may be present among wild fauna is of importance primarily because of the potential hazard to susceptible domestic species allowed to graze on land which is, for the present, presumed free of infection. Since louping-ill is exclusively a tick-borne disease, it is possible that if susceptible wild species exist they may assist not only in maintaining a population of infective ticks and thus in providing a reservoir of infection for domestic animals, but also in the transference of ticks and infection to other regions and the establishment of new infective areas.

Milne (1949) gives the wild mammalian hosts upon which one or more stages of *Ixodes ricinus* may survive in Britain as deer, hedgehog, fox, stoat, weasel, ferret, wild-cat, hare, rabbit, rat, mouse and squirrel. Many of these species may be discounted as possible reservoirs of louping-ill infection because they are seldom found in hill areas in large numbers or because of their proved insusceptibility to generalized louping-ill infection. The deer, however, though its susceptibility has never been investigated might be subject to infection because of its close zoological relationship to the natural hosts, sheep and cattle.

The red deer population of Scotland is estimated as approximately 84,000 on a deer forest area of 3,084,000 acres, over most of which the animals have free range. The distribution is wide, the species being found in the mountain areas of most of the mainland and on many of the Western Isles. Density is extremely variable, the best deer land being capable of supporting one animal on 30 acres while other regions may carry only one deer on 100 acres (Darling, 1937). As with sheep, however, the density of the population is governed by available grazing so that the animals in an area may habitually graze only a few acres of the total.

Red deer spend their time in favourite resting places which they may frequent for long periods. Engorged ticks therefore tend to be concentrated in these lairs, and will immediately find a host after they have moulted, so that infestations may be of the order of 500 or, in extreme cases, nearly 1,000 females per deer (Macleod, 1938).

Material and Methods

Since the direct investigation under laboratory conditions of the susceptibility of the larger wild mammals to louping-ill infection is almost impracticable, inquiry was confined to the identification and titration of specific immune body in serum.

Blood samples were collected by stalkers and sent by mail to the laboratory, where the serum was removed by centrifugation and stored at 0°—4° until tested. The samples were examined by the serum-virus neutralisation method and in the results given below the interpretation is that recommended by Rivers (1948), where neutralisation indices of 0—9 are presumed negative, 10—49 doubtful and 50 or more positive.

RESULTS

A total of 300 samples from deer on 60 different forests were examined. Since deer forests are seldom enclosed and the animals have free range over wide areas, the results are grouped in regions which have natural boundaries tending to limit deer movement.

The total area represented by the sampling was 750,000 acres, subdivided in Table I into the following regions:—

Region I. Mainland north of Coigach—Strathoykell line.

Region II. Ross and Cromarty and Western Inverness-shire north of the Great Glen.

Region III. Inverness-shire, Perthshire, Dumbartonshire and Argyll, bounded on the east by the Rivers Spey, Tummel and Garry, and on the south by the Forth-Clyde lowland area. (This region is further subdivided into East and West regions by a natural grouping of the forests.)

Region IV. Aberdeenshire, Kincardineshire, Angus and part of Inverness-shire east of the Spey-Tummel-Garry line.

Region V. South-West (Kirkcudbright and Wigtownshire).

Region VI. Western Isles.

The percentage of positive results in the various regions is set out in Table I.

TABLE I. PROPORTION OF DEER WITH SERUM ANTIBODIES TO LOUPING-ILL VIRUS IN VARIOUS AREAS OF SCOTLAND.

Region	Stags per cent positive	Hinds per cent positive
I	24	—
II	44	29
III (East)	13	—
III (West)	47	14
IV	37	23
V	0	0
VI	59	0
Percentages of total samples	37	22

The positive percentages arranged according to age groups are shown in Table II.

The neutralising indices varied over a wide range and showed no significant distribution with regard to age. In sheep and cattle neutralising indices of more

than 100 are indicative of past active infection. The mean index of all deer sera examined was 829, while in four cases indices of 10,000 were observed. Twelve samples from fallow deer in the New Forest, from which louping-ill is absent, were examined as controls and proved negative.

TABLE II. PROPORTION OF DEER WITH SERUM ANTIBODIES TO LOUPING-ILL VIRUS ARRANGED ACCORDING TO AGE. POSITIVE SPECIMENS PER CENT.

Age (years)	Stags	Hinds
2 and under	10	0
3—5	30	87
6	48	60
over 6	65	43

An investigation was made also of some features of the nature of the forests and their adjacent areas. The results are summarised below.

Domesticated Species Present

On the majority of deer forests a permanent stock of sheep, and often of cattle as well, is carried, though in certain areas the stocking is confined to the summer months. With the exception of those under the control of the Forestry Commission which are ring-fenced, and to which deer only occasionally have access, none of the forests investigated was completely free of sheep.

Ticks

Certain forests in the northern part of Region I (Sutherland) do not record the presence of ticks, and there appears to be another area (around and including Ledgowan and Glenfeshie) of Region II which is tick-free. These areas apart, however, ticks appear to be present on all the 750,000 acres investigated. In the west, and especially on the sheep grazings, the incidence of tick infestation is very high.

Louping-ill

While it appears to be the case that wherever ticks are numerous louping-ill infection occurs in sheep and cattle, the present inquiry has shown that, in areas adjacent to tick-free territory where the tick population may be low, the disease has not been recognised. Vaccination of sheep and cattle is widely practised, although on some estates it is applied only to newly imported stock. None of the estate owners, factors and stalkers from whom information was sought had recollections of symptoms resembling louping-ill in red deer.

DISCUSSION

The presence of appreciable titres of specific virus-neutralising antibody in their sera indicates that louping-ill virus can become established and multiply in the red deer and thus that these animals are susceptible to the infection. (Rivers and Schwentker (1944) demonstrated by neutralisation tests that man was susceptible to louping-ill infection though virus had never been recovered from the

blood stream). That active multiplication of virus occurs is shown by the high titres attained in some cases, but the absence of records of clinical disease amongst deer stocks suggests that the infection has a subclinical or inapparent course. The age distribution of positive titres indicates that many animals may reach an age of two years before undergoing active infection.

Milne (1950) has shown that spatial distribution of *Ixodes ricinus* depends upon two main factors: ground cover, *i.e.*, protection from adverse conditions of humidity and temperature, and host-potential. Adequate ground cover exists upon the majority of deer forests, and the host-potential is relatively high owing to the herding habits of the hind groups and, as has been pointed out, the preference of deer for favourite lairs which they occupy day after day and, in some cases, year after year so that ticks become most numerous there. It follows, therefore, that within their own communities conditions are present which may allow deer to maintain louping-ill infection in the absence of sheep and cattle.

Ticks are present on most of the deer forest investigated, and the significance of the present inquiry lies in the possibility of introduction of louping-ill infection into existing tick stocks rather than in the spread of ticks to new areas. Since hind groups tend to remain on their own grazings, stags bear the greater importance in this respect. The largest numbers of travelling stags are found in late spring, when the stag groups return from wintering, often on sheep pasture, and in autumn and early winter when their journeys to rutting areas and wintering grounds occur. It is noteworthy that these periods of stag-migration coincide with the two periods of maximum tick activity when the probability of transport of infective ticks is greatest but, since the migrations of deer are probably confined to habitual routes, transference of infection to new areas is unlikely. Only in the event of a large scale and erratic movement of the animals would the establishment of new areas of infection appear possible.

Acknowledgments

This investigation was made while the writer was on the staff of the Animal Diseases Research Association, Moredun Institute, Edinburgh, to the Director and staff of which he is indebted for the facilities and encouragement given.

It is impossible to mention individually the many estate owners, factors and stalkers who have been of assistance in this investigation. Without their co-operation, often under very difficult conditions, no observation could have been made. The writer would, however, especially express his thanks to Mr. G. F. Baird, who arranged sampling on several forests under his care, Captain J. S. Fletcher, Ardlussa, and Lt.-Col. Moncrieff, Kinloch, and to Mr. Donald MacDougall, head stalker on Kingairloch who provided much valuable and detailed information.

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REVIEWS

VETERINARY APPLIED PHARMACOLOGY AND THERAPEUTICS. By P. W. Daykin. London: Baillière, Tindall & Cox. 55s.

The writer had the privilege of reviewing, in the April issue of the BRITISH VETERINARY JOURNAL, a small book by Dr. F. Alexander entitled *An Introduction to Veterinary Pharmacology*. To the student who approaches for the first time the wide field of pharmacology and therapeutics, be it medical or veterinary, an introduction is very desirable, but once the elementary principles have been mastered it soon becomes apparent that a more detailed source of information is required. To this extent, therefore, these two volumes may perhaps be considered complementary. In some measure, the need for detailed information may be met by reference to the *British Veterinary Codex*, but here, as with the *British Pharmacopoeia*, the information given is strictly limited in its scope. Daykin's work fulfils the need for fuller information than that given in the official publications such as the *Codex*, and thus emulates such standard works as that of Martindale and Squire in the field of human therapeutics.

The author and those whose help and advice he has been fortunate enough to have enlisted are to be congratulated on the results of their labours. Doubtless much of the material was assembled whilst they were preparing lectures on the subject — the general arrangement chosen for dealing with the various drugs shows evidence of this — but even so, the production of the book represents a task of considerable magnitude, more especially since there has been a veritable flood of new products introduced into veterinary practice within recent times.

In view of the multiplicity of drugs which are mentioned in the text, it is surprising that diethylcarbamazine has been omitted, especially since it has recently been revived in veterinary medicine as a treatment for parasitic bronchitis. Obviously there must be some time lag between preparation and publication which makes it impossible to ensure that any work can be entirely up to date, and this is probably the explanation for the omission of this drug. The process of its manufacture was patented by the manufacturers some years ago when they introduced it for the treatment of filariasis in man. Later it was used as an ascaricide for dogs and cats. Although the piperazine compounds have replaced it for this purpose its retention in a reference book would have been desirable, although it might well be argued that its inclusion in a student's text book such as this was unnecessary at the time of writing.

The work was compiled to replace that well-known veterinary classic, *Hoare's Veterinary Therapeutics*, which, after its appearance in the latter years of the last century, ran to many editions. The present book is a worthy successor, yet it differs in so many ways that it must be regarded, not as another edition of an old work, but as an entirely new book. The reviewer predicts that it will establish itself as did the book which it replaces and will securely occupy the niche in veterinary literature vacated by its forerunners.

H. BYWATER.

AN INTRODUCTION TO HUMAN BLOOD GROUPS. By Fulton Roberts. London: William Heinemann — Medical Books. 9s. 6d.

Blood groups constitute an established branch of human pathology. Their significance in livestock disease is now being increasingly recognized. Haemolytic disease occurs in both horses and pigs. In poultry, there are suggestions of relationships between blood types and fitness, and similar associations probably exist in

other species. It is desirable, therefore, that veterinarians in general have some knowledge of blood grouping.

Veterinarians who are non-specialists but interested in the subject will find Dr. Roberts' lucid and concise book a useful introduction. While it is written more from a clinical than a genetical standpoint, the scientific and cultural aspects of blood groups are briefly indicated.

As the title suggests, it deals mainly with humans and not domestic animals. Those, however, who have had their interest stimulated, will find the veterinary aspects of the subject already well dealt with in Dr. Roberts' earlier work, "The Comparative Aspects of Haemolytic Disease of the Newborn."

G. B. YOUNG.

ANNUAL REPORT AND YEAR BOOK, 1959-60. *Association of British Pharmaceutical Industry.*

Drug costs are high and continue to rise. Are they higher than they need be? No figures are available for veterinary sales alone but earlier this year the Auditor General*, discussing the reasons for the rise in cost of prescriptions under the National Health Service, made some relevant points. He noted that 70 per cent. of prescriptions were for proprietary preparations, many of which were in categories classified as having active constituents indentical with, or modifications of, the cheaper standard preparations. The cost of drugs in these categories is governed by a voluntary price regulation scheme. This scheme comes under review this year and, as it has resulted in a smaller saving to the National Health Service than was originally estimated, it will probably be replaced. The Auditor-General also noted that profits were higher in the pharmaceutical industry than in industry generally. This was particularly the case with British subsidiaries of United States firms.

The Annual Report and Year Book of the A.B.P.I. merits attention as containing the pharmaceutical industry's reply to these criticisms. It points out that new drugs must be introduced in proprietary form to allow the manufacturers to recoup the considerable sums of money expended on research, and that many proprietary drugs have no standard equivalent. It does not mention, however, the numerous proprietary preparations which are simply a mixture of standard drugs or a slight modification of existing ones. In such cases research costs must be minimal. The Report defends the high percentage profits in the pharmaceutical industry on three grounds:

1. The need to provide adequate funds for research.
2. The unusually high risks involved in making a product which can be so easily superseded.
3. The rapid depreciation of plant.

The profits shown by subsidiaries of U.S. firms are said to *appear* high because published accounts do not show the substantial costs borne for subsidiaries by their parent firms.

Meanwhile the veterinary surgeon may be permitted to ponder whether all is well with a system under which, while the Veterinary Therapeutic Testing Board languishes in desuetude, he is largely reliant on direct mail advertising to keep him informed on a mass of drugs bearing proprietary names quite unrelated to any orderly system.

P. M. KEEN.

* Report of the Comptroller and Auditor-General on the Civil Appropriation Accounts (Classes I-V) for 1958-59.

AIDS TO FORENSIC PHARMACY. By H. W. Fowler, 5th Edition. London: Baillière, Tindall & Cox. 12s. 6d.

This pocket-sized book, one of the well-known "Students' Aid" series, is a summary of the legislation relating to the manufacture, sale and dispensing of pharmaceutical preparations. In the 5th edition it has been enlarged to include two chapters on preparations of purely veterinary interest. It is heartily recommended to anyone, be he student or practitioner, who wishes to refer to pharmacy regulations in a concise, readable form devoid of the sub-paragraphs and "hereinafters" of the originals.

P. M. KEEN.

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Worden A. N. 1958 a. "The feeding of fresh and stored chick mashes containing cod liver oil". Journal of Agricultural Science, Volume 50, number 3, pages 340 and 343.

Worden A. N. 1958 b. "The feeding of cod liver oil to growing fattening pigs". Journal of Agricultural Science. Volume 50, number 3, pages 344-345.

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